#4

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

JC503 U.S. PTO
10/022398
10/30/01

In re Application of

CYRIL ALLOUCHE

Serial No.

Filed: CONCURRENTLY

Atty. Docket

FR 000116

Group Art Unit

Ex.

Title: METHOD AND SYSTEM FOR TAG DETECTION AND TRACKING IN MRI TAGGED IMAGES

Commissioner for Patents
Washington, D.C. 20231

AUTHORIZATION PURSUANT TO 37 CFR э1.136(a)(3)
AND TO CHARGE DEPOSIT ACCOUNT

Sir:

The Commissioner is hereby requested and authorized to treat any concurrent or future reply in this application requiring a petition for extension of time for its timely submission, as incorporating a petition for extension of time for the appropriate length of time.

Please charge any additional fees which may now or in the future be required in this application, including extension of time fees, but excluding the issue fee unless explicitly requested to do so, and credit any overpayment, to Deposit Account No. 14-1270.

Respectfully submitted,

By
Michael E. Marion, Reg. 32,266
Attorney
(914) 333-9641

S:\VO\ML26VOb0.RU0.doc

FR000116
US

Europäisches Patentamt

European Patent Office

Office européen des brevets

JC503 U.S. PTO
10/022398
10/30/01

Bescheinigung

Certificate

Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

00403028.4

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

Hatten

I.L.C. HATTEN-HECKMAN

DEN HAAG, DEN
THE HAGUE, 03/08/01
LA HAYE, LE

EPA/EPO/OEB Form 1014 - 02.91

Europäisches Patentamt | European Patent Office | Office européen des brevets

Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 00403028.4
Demande n°:

Anmeldetag:
Date of filing: 31/10/00
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
Koninklijke Philips Electronics N.V.
5621 BA Eindhoven
NETHERLANDS

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Method and system for tag detection and tracking in MRI tagged images.

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
/

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

Field of the Invention

The invention relates to an image processing method to detect "tag" points in a "tagged" image of a sequence of images, said "tags" being the pattern observed on the "tagged" image resulting from the spatial modulation of the magnetization in the observed zone. The invention relates to every kind of modulation patterns that can be parameterized in the frequency domain. Tags can be, for example, straight lines on one modulation direction (SPAMM protocol), straight lines on several directions generating every kind of grids (SPAMM protocol) or generating radial patterns and circles of different diameters. In the following a tag would designate any kind of constitutive part of a larger pattern that can be parameterized in the frequency domain. Generally it would be a straight or a curved line at the beginning of a sequence, this line being then deformed by the movement of the zone wherein the magnetization is modulated. Following the tag and its deformation is an issue of the invention.

The invention also relates to a computer program product wherein the method is implemented, to an image processing system and to an MRI apparatus to carry out the method.

The invention finds its application in Magnetic Resonance Imaging (MRI).

Background of the Invention

A semi-automatic image processing method for detecting tag points is already known from a publication by M. Guttman et al. entitled "Tags and Contour Detection in Tagged MR Images of the Left Ventricle" published in IEEE Trans. Med. Imaging, 13:74-88, 1994. This article relates specifically to tag lines. As described in this publication, the user initializes tag line points and these points are followed by an algorithm based on a dynamic programming, which is guided by the user from an image to an other by using an intensity profile. The attribution of a point to a tag line is always checked by the user as a point could easily be affected to two neighboring tag lines. This method does not use any modeling of tag lines nor any predicted movements of tag lines. According to this known method, the image processing is slow and is consequently difficult to implement in view of diagnosis clinical applications. Moreover, since the algorithm is not fully autonomous for tracking the tag lines, this known method requires many user interactions for yielding a valid tracking of a tag line from an image to the following image. Besides, the accuracy of the detection of tag points is not validated by any analysis or movement reconstruction.

Summary of the Invention

It is an object of the present invention to provide an image processing method to fully automatically detect with accuracy tag points in an MRI image that is tagged according one modulation pattern as described in the introduction.

It is to be noted that in an image of a sequence of images, each tag shows a motion from a current image to the following one. Current image being defined as the image of the sequence at time (t) wherein tag points are under detection, time t being incremented from the start to the end of the sequence. According to the invention, said motions of tags is taken into account. The motions of tags are predicted by spatial and temporal continuity to yield a predicted image, which predicted image is further used to detect tag points in a next-in-time image.

It is an object of the invention to yield such a predicted image with sufficient information to allow an accurate detection of tag points.

In accordance with the invention, an image processing method to detect tag points in a current tagged image of a sequence of tagged images, comprises steps of :

in the current image, estimating points having optimum intensity values in intensity profiles and labeling said points as candidate points of a tag ; using a previously constructed predicted image constituted of predicted tags determined from tags equations of a previous-in-time image of the sequence and from spatial and temporal parameters ; and, in the current image, detecting tag points among said candidate points from said previously constructed predicted image ; determining tags equations for the current image from said detected tag points ; using said tags equations in the construction of a further predicted image for processing a next-in-time image of the sequence.

The determination of an equation for each tag of each image of the sequence, that is a modeling of tags, allows to work with whole tags, for example, whole lines, instead of points to estimate motions from one image to another. As, according to the invention, whole tags are available, instead of only points on more or less interrupted straight or curved line, and as an equation of each tag is known, it is possible to construct, by spatial and temporal continuity, a predicted image constituted of predicted tags, for a next-in-time image, which predicted image is rich of information since whole tags positions are predicted. Moreover, knowing the likely positions of each tag as a whole allows to determine the belonging of a candidate point to a specific identified tag : an automatic tracking of tags is consequently performed from an image to another, from the beginning of the sequence where the identification of specific tags is easy from the end where motions of tags render the identification harder. An other advantage of the algorithms working on whole tags, according to the invention, is their fastness.

In an embodiment, the method of the invention comprises steps of computation of equations of tags by using a Rational Fitting from the detected points. Said Rational Fitting can be

used alone or in combination with a further fitting using a Residue Technique. The obtained detection is very accurate as this particular mathematical expression of tags allows a very good fitting to real tags, especially when tags are straight lines at the beginning of the sequence, and consequently allows to construct trustful predicted tags for next-in-time images.

In an embodiment, the method of the invention comprises steps to evaluate the belonging of a candidate point to a specific identified tag even when using a low temporal resolution. Effectively, the longer is the time between two images of the sequence, the larger is the motion of tags from an image to the following. Consequently, even when using modeling of tags according to the invention, there is a chance to select a point as belonging to a given tag although, in reality, this point is belonging to another appropriate tag.

In an embodiment, the invention takes into account that the intensity profile of an MR image presents minimum of magnetization that are classically considered as constituting the tags, and maximum, less detectable than said minimum, that are generally very sharp, and that constitute another family of tags, labeled positive tags. Two tags corresponding classically to a minimum of magnetization are always separated by a positive tag. Optimum points estimated by the image processing method of the invention include the points corresponding both to maximum and minimum values. The points corresponding to maximum values are especially well localized when working on CSPAMM protocol images as these images present a good contrast. The method of the invention comprises steps to use the alternating pattern of these two kinds of tags and their spatial characteristics in order to detect tag points and in order to determine with a great accuracy to which specific tag a point belongs.

In an embodiment of the invention, the detection step using characteristics of the predicted image comprises sub-steps of :

distinguishing two kinds of tags : negative tags corresponding to minimum of magnetization and to a maximum of intensity in the intensity profile, and positive tags corresponding to maximum of magnetization and to a minimum of intensity in the intensity profile ;

distinguishing two kinds of candidate points : candidate points being optimum value points corresponding to a maximum of intensity in the intensity profile, and candidate points being optimum value points corresponding to minimum of intensity ;

selecting points of a negative tag D as being the candidate points corresponding to the maximum of intensity that are situated between the two predicted positive tags that surround the predicted negative tag that corresponds to the negative tag D, and

symmetrically selecting the points of a positive tag.

The delimitation of the region where tag points can be detected requires to use whole predicted tags, that is the main feature of the invention. This delimitation brings the advantage of

critically reducing the chance to select a point belonging to a given tag of one kind to another tag of the same kind, what was current when classically using only negative tags. Moreover, the use of maximum value tags brings the advantage of providing more points than classical techniques using only tags corresponding to minimum value of magnetization. Characteristics of the predicted image are consequently richer allowing a more accurate detection of tag points and a better tracking of the tags, especially in case of low temporal resolution.

In an embodiment, the method comprises a step of automatically constructing a predicted image including sub-steps of choosing a given number of privileged points on tags of the previous-in-time image of the sequence ; calculating from positions of said privileged points in the previous-in-time image of the sequence, a predicted position of said privileged points ; constructing predicted tags of the predicted image from predicted positions of said privileged points. This last step can comprise sub-steps of estimating a minimizing function (f) that minimizes the distance between the predicted positions of privileged points and the result of the application of this minimizing function (f) to these privileged points ; applying the minimizing function (f) to tags equations of the previous-in-time image of the sequence to construct the tags of the predicted image. Said minimizing function (f) can be a function of similarity expressed as $f(z)=lz+c$, where l and c are complex parameters.

In an advantageous embodiment of the invention, privileged points are intersection points between tag lines obtained from an MR image tagged on two distinct directions or between tag lines obtained from two MR images each tagged in one direction distinct from the tagging direction of the other, said two MR images corresponding to a similar step of the sequence. The intersection points are calculated from the two tag line equations. The use of this feature presents a particular advantage since these points are easily identifiable on every images of the sequence and, consequently, can be easily tracked from an image to another.

By working on whole tags instead of working on points, the method of the invention allows a fast processing of images, since an algorithm working on whole tags knowing an equation for each of them is low resource consuming. Resource consumption can be further reduced by using an image segmentation, for separating region of interest from other regions where tag lines exist but do not provide information of interest.

The invention first allows a very reliable detection of tag points and consequently allows a good tracking of tags from an image of a sequence to another along the sequence.

Brief Description of the Drawings

The invention is described hereafter in detail, with reference to the schematic drawings wherein :

Fig. 1 is a flow chart for illustrating a method of detecting tags ;

Fig. 2 is an intensity profile of an MR image in the modulation direction in the case of a one direction modulation of magnetization ;

Fig. 3 is an example of a spatial condition used for selecting tag points ;

Fig. 4a and Fig. 4b are two examples of MRI apparatus for carrying out the method of the invention.

Detailed Description of the Embodiments

FIG. 1 is a flow chart that illustrates an image processing method according to the invention. On this diagram, processing steps are illustrated by oval blocks and the results of the processing steps are illustrated by rectangular blocks.

Referring to FIG. 1, the image processing method has iterative steps applied to a sequence of tagged images for tracking tags on successive images of a sequence of MRI tagged images. According to this method, tag points are detected by using a predicted image constructed from, at least, the previous-in-time image. Then, the detected tag points are affected to a specific tag, said specific tag being consequently "tracked" from an image to the following image.

An initialization step 11 is required as, for the first image of the sequence, at a first instant called time t_0, there is not any previous-in-time image available to construct a predicted image. The first image of a sequence of tagged images is a non-deformed image presenting, for example, straight and parallel tags. These straight and parallel tags correspond to the case of one direction line modulation or grid pattern modulation that are preferred features for the invention. Consequently, the initialization step 11 constructs a first set of equations of tags $T(t_0\text{-}1)$ (12) at a previous instant called time (t_0 -1) describing, for example, straight and parallel lines. This first set of equations is then used for constructing a predicted image serving for the detection of tag points of image at time t_0. The method according to the invention is effectively then implemented on a current image 10 at a current instant called time t of the sequence from t_0 to $t_{\text{end of the sequence}}$, which current image is denoted by image I(t). An estimation step 13 applied to said current image I(t) 10 estimates optimum points denoted by CP(t) 14 and labeled Candidate Points.

Then, a detection step 15 performs a detection of tag points denoted by TP(t) 16. This detection step 15 detects the tag points TP(t) 16 of the tags among the candidate points CP(t), using characteristics of a predicted image PI(t) 17 automatically determined by a construction step 18 of the predicted image PI(t)

In the construction step 18, the predicted image PI (t) is constituted of predicted tags, which are computed from tags equations 19 of, at least, a previous-in-time image of the sequence with respect to the time t of the current image and from spatial and temporal parameters, said tags equations being noted as T(t-1). This construction step 18 uses temporal parameters by using, at least, tags T(t-1) provided at an instant (t-1) 19 but can also use tags T(t-2) of an

instant (t-2) and tags T(t-3) of an instant (t-3) 22 and so on as soon as these data are available from the processing of images of the sequence.

According to an advantageous embodiment of the invention, a spatial condition using the intensity gradient of the predicted image PI(t) 17 as a spatial parameter allows to discard the most part of contour points and noise. At each point of the predicted image PI(t) 17, an orientation angle, denoted by $\beta(x,y)$, is given by the normal vector to the predicted tags. Mere interpolation techniques, such as bilinear interpolation, enables to compute this angle $\beta(x,y)$ for every point in the predicted image. A maximum error coefficient α (the same for every point) is attributed for $\beta(x,y)$ in the whole image, said coefficient α depending of the noise level of the real-world images. Candidate points selected using this spatial condition are the ones where the gradient direction lie in $\beta(x,y)$ +/- α. This spatial condition application is used to discard the most part of contour points and noise. Another spatial condition using the distance of a candidate point from predicted tags as a spatial parameter can be implemented, said distance being included within a given range or being function of positions of the predicted tags.

In an example, spatial conditions on distance use the fact that, referring to FIG. 2, the intensity J(x) profile in the modulation direction of an MR image tagged in one modulation direction x presents minimum value points m of magnetization that are classically considered as constituting the tags, here noted negative tags and maximum value points M, less stable than minimum value points m that are generally very sharp. These maximum value points M constitute another family of tags, labeled positive tags. Minimum value and maximum value points are characterized and, further localized, by cancellation of the derivative function. Using classical image processing, maximum value points M can be distinguished from minimum value points m. Although maximum value lines are less detectable than minimum value ones, the use of maximum value points allows to work on a narrower grid of tags as when using only minimum value points as done classically.

In an embodiment of the invention, an advantageous spatial condition on the distance of a candidate point from predicted tags of the predicted image can be implemented in order to use the predicted positive and negative tags and their alternating patterns, since two tags are always separated by a positive tag, and vice versa. For example, as illustrated on FIG.3, the candidate points corresponding to minimum intensity value and represented by a $\times$ and lying between predicted tags $\hat{D}_n^+$ and $\hat{D}_{n+1}^+$, and near enough to predicted tag $\hat{D}_n$ are assigned to tag D_n. Predicted entities are noted with a ^. This enables to affect the detected tag points to specific tags without ambiguity whatever is the used tag pattern. This feature is especially interesting when the sequence is acquired with a low temporal resolution.

Tag points 16, obtained after the tag point detection step 15, are used in a determination step 20 to determine the tags T(t) 21 of I(t) (FIG. 1).

A technique of determination of the tag equations is proposed hereafter : In a preferred embodiment, a Numerical Rational Approximation Algorithm is applied to calculate equation of tags from selected tag points. This approximation is a first "rigid" representation of tags in the space of rational functions with degree inferior to 4 and noted $FR_{4,4}$. These functions are able to interpolate smoothly in informationless zones (typically inside the myocardium), far better than polynom-based interpolators. Given a set of p points $\{(x_i, y_i), i=1 \ldots p\}$ labeled to a same tag, the best rational least square approximation on function $y=f(x)$ can be computed to find :

$$Inf_{f \in FR_{n,n}} \left(\sum_{i=1}^{p} \left((f(x_i) - y_i)^2 \right) \right) \quad \text{with } f : x \rightarrow \frac{\sum_{k=0}^{n} a_k x^k}{\sum_{k=0}^{n} b_k x^k}.$$

Consequently the following iterative problem is introduced :

$$(\hat{P}_n, \hat{Q}_n) \leftarrow Inf_{P,Q} \left(\sum_j \left(\frac{P(x_j) - Q(x_j) y_j}{\hat{Q}_{n-1}(x_j)} \right)^2 + k_1 \int_{x_m}^{x_M} \left(\frac{P(x) - Q(x) \hat{f}_{n-1}(x)}{\hat{Q}_{n-1}(x)} \right)^2 dx + k_2 \int_{x_m}^{x_M} \left(1 - \frac{Q}{\hat{Q}_{n-1}} \right)^2 \right)$$

The discrete approximation of the two integrals by Riemann sums leads to a linear system in $\{a_i, b_i\}$. The convergence is rapidly observed in practice.

In an advantageous embodiment, a second level of approximation is added, to locally compensate the error. Named "elastic" representation, this approximation use I_δ that is a partition $\{[x_i, x_{i+1}], i=1 \ldots n\}$ of step δ along the x-axis. On $[x_i, x_{i+1}]$, the residue R_i is expressed by the median of the error between a sample and the rational function. Then, the error is :

$$E(x) = \left(\sum_i R_i \chi_{[x_i, x_{i+1}]} \right) * e^{-(x/\sigma)^2}.$$

That is to say the convolution of the step-function $(R_i)_i$ by the centered gaussian of standard deviation σ. $E(x)$ simplifies in :

$$E(x) = R_1 erf(x/\sigma) - R_n erf((x - x_n)/\sigma) + \sum_{i=1}^{n-1} \frac{1}{2} (R_{i+1} - R_i) erf((x - x_i)/\sigma).$$

Hence, the description space for tags equations is formally :

$$FR\varepsilon_{\sigma,I_\delta} = FR_{4,4} + Vect\left\{er\ f\left(\frac{x-x_k}{\sigma}\right),\ k\right\} \subset C^\infty$$

Equations found by this fitting allows to very closely fit to real tags. A trustful construction of the predicted image can then be realized.

A predicted image construction is further proposed hereafter : Tags T(t-1) are used in a predicted image construction step 18 (FIG. 1), which uses the tags equations from at least the previous-in-time image, for the construction of a predicted image then used to process I(t) from a given sequence.

In an embodiment of the invention, privileged points are chosen among points on the tags of at least a previous-in-time image. A predicted position of each of said privileged points for the time of the next-in-time image of the sequence is evaluated from positions of said privileged points on, at least, the previous-in-time image.

In an advantageous embodiment, tags are lines and equations of tags are known in two distinct directions, from an MRI image tagged on two distinct directions or from two MRI images, corresponding to similar times of the sequence. Each of the two MRI images is tagged in one direction distinct from the tagging direction of the other, and privileged points positions are calculated as being intersection points between tag lines in the two distinct directions. It is important to note that intersection points are advantageously used because they are easily identifiable on every images of the sequence and, consequently, can be easily tracked from an image to another. It is further important to note that when using intersection points while working with maximum and minimum magnetization tag lines, a very dense mesh of tag lines and a dense set of intersection points is obtained, enabling a very accurate determination of movements of tag lines.

In an example, in order to calculate a predicted position for privileged points, the acceleration of privileged points is considered as being constant. The discrete scheme is then, for example, a third order linear filter :

$$\hat{A}_{i,j}^{n} = 3A_{i,j}^{n-1} - 3A_{i,j}^{n-2} + A_{i,j}^{n-3}.$$

Predicted entities are noted with a ^ and, in this example, tag points from three previous-in-time images is used as soon as these three images are available. From the set of points obtained, predicted tags can be constructed by employing an approximation among a spline function approximation or a rational approximation or any kind of interpolation.

In a preferred embodiment, the motion is constrained by estimating a function (f) that minimizes the distance between the predicted positions of privileged points and the result of the application of this function (f) to these privileged points and by applying the function (f) to tags equations of

the previous-in-time image of the sequence to construct the tags of the predicted image. For example, a similarity, transformation composed of a rotation, a translation and a scale change, expressed in the complex plane as :

$$f(z) = \lambda z + c, \lambda, c \in \mathbb{C}$$

is used to constrain the motion. The module of λ gives the scale factor, while its argument is the rotation angle. c is the translation vector. In this form, the optimization of λ and c in the sense of the least squares criterion, can be implemented by the pseudo-inverse method in $\mathcal{M}_n(\mathbb{C})$ using the privileged points. The predicted tags are then computed by applying the $f(\lambda,c)$ transformation to the former equations of tags of the previous-in-time image.

Once the predicted image has been constructed, it can be provided to a tag points detection step 15 (FIG. 1) in order to select tag points of a next-in-time image.

FIG. 4 illustrates the main features of an example of an MRI apparatus 30 to carry out the method as shown on Fig. 2. The MRI apparatus includes an acquiring system 31 to acquire data from a site of the body 32. Said data are provided to a processing system 33, generally included in the MRI apparatus 30 as illustrated on Fig. 4a. In a variant, this processing system 33 can be implemented in a computer 34, independent from the MRI apparatus 30 but in relation with it, as illustrated on Fig. 4b. The processing system 33 executes a set of instructions according to a program. The program causes the processing system 33 to carry out the method of the invention on data provided by the acquiring system 31. Said processing system 33 is in relation with a display equipment 35 to display processed data.

The drawings and their description herein before illustrate rather than limit the invention because there are numerous ways of implementing functions by means of items of hardware or software, or both. In this respect, the drawings are very diagrammatic, each representing only one possible embodiment of the invention. Thus, although a drawing shows different functions as different blocks, this by no means excludes that a single item of hardware or software carries out several functions. Nor does it exclude that a function is carried out by an assembly of items of hardware or software, or both. Any reference sign in a claim should not be construed as limiting the claim. The word "comprising" does not exclude the presence of other elements or steps than those listed in a claim. The word "a" or "an" preceding an element or step does not exclude the presence of a plurality of such elements or steps.

CLAIMS

1. The image processing method to detect tag points in a current tagged image of a sequence of tagged images, comprising the steps of:

in the current image, estimating points having optimum intensity values in intensity profiles and labeling said points as candidate points of a tag;

using a previously constructed predicted image constituted of predicted tags determined from tags equations of a previous-in-time image of the sequence and from spatial and temporal parameters; and,

in the current image, detecting tag points among said candidate points from said previously constructed predicted image;

determining tags equations for the current image from said detected tag points;

using said tags equations in the construction of a further predicted image for processing a next-in-time image of the sequence.

2. The image processing method of claim 1, wherein the tags equation determination step from detected tag points uses a rational fitting from the detected points, said rational fitting being used alone or in combination with a further fitting using a Residue Technique.

3. The image processing method of one of claims 1 and 2, wherein the detection step from said previously constructed predicted image, comprising the sub-steps of:

distinguishing two kinds of tags : negative tags corresponding to minimum of magnetization and to a maximum of intensity in the intensity profile, and positive tags corresponding to maximum of magnetization and to a minimum of intensity in the intensity profile;

distinguishing two kinds of candidate points : candidate points being optimum value points corresponding to a maximum of intensity in the intensity profile, and candidate points being optimum value points corresponding to minimum of intensity;

selecting points of a negative tag D as being the candidate points corresponding to the maximum of intensity that are situated between the two predicted positive tags that surround the predicted negative tag that corresponds to the negative tag D, and

symmetrically selecting the points of a positive tag.

4. The image processing method of one of one of claims 1 to 3, wherein the step of constructing a predicted image comprises sub-steps of:

choosing a given number of privileged points on tags of the previous-in-time image of the sequence;

calculating from positions of said privileged points on, at least, the previous-in-time image of the sequence, a predicted position of said privileged points; and

constructing predicted tags of the predicted image from predicted positions of said privileged points.

5. The image processing method of claim 4, wherein the step of constructing predicted tags from predicted positions of said privileged points comprises sub-steps of:

estimating a function (f) that minimizes the distance between the predicted positions of privileged points and the result of the application of this function f to these privileged points;

applying said function (f) to tags equations of the previous-in-time image of the sequence to construct the predicted tags of the predicted image.

6. The image processing method of claim 5, wherein the function (f) is a similarity expressed as f(z)=lz+c, where l and c are complex parameters.

7. The image processing method of one of claims 4 to 6, wherein privileged points are intersection points between tags obtained from an MRI image tagged in a grid pattern on two distinct directions or between tags obtained from two MRI images each tagged in a straight and parallel lines pattern in one direction distinct from the tagging direction of the other, said two MRI images corresponding to a similar step of the sequence, said intersection points being calculated from the tags equations.

8. The processing method of one of Claims 1 to 7, to be applied to, at least, a sequence of MRI tagged images, to track tags on successive images of the sequence, comprising steps of:

initializing the processing method by implement one of the method of claims 1 to 7 for the first image of the sequence, using a first predicted image representing the non-deformed modulation pattern;

iteratively implementing the image processing method of one of the claims 1 to 7 for the following images of the sequence.

9. A computer program product comprising a set of instructions for carrying out one of the methods as claimed in claim 1 to 8.

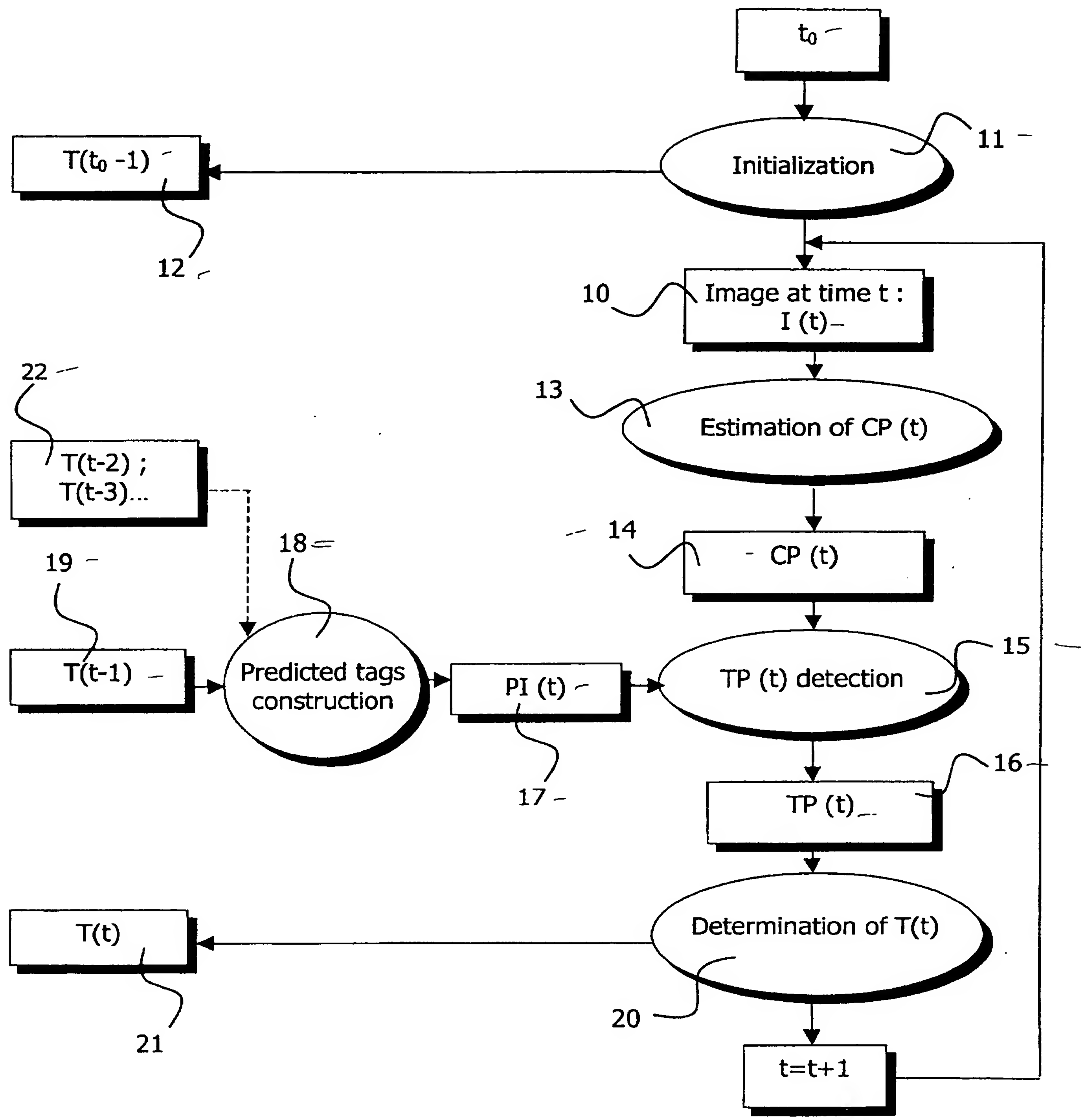
10. A system for processing images of a sequence of MRI tagged images, comprising:

Means for detecting tag points of these images according a method as claimed in one of Claims 1 to 8;

Means for displaying the results as a succession of images wherein tags are visible.

11. An MRI apparatus comprising:
Means for acquiring sequences of MRI images from a site within a body;
Processing means including a system as claimed in claim 10.

THIS PAGE BLANK (USPTO)



t_0
Initialization
11
$T(t_0 -1)$
12
Image at time t : I (t)
10
Estimation of CP (t)
13
22
T(t-2) ; T(t-3)...
14
CP (t)
18
19
T(t-1)
Predicted tags construction
PI (t)
TP (t) detection
15
16
TP (t)
17
T(t)
Determination of T(t)
20
21
t=t+1

FIG.1

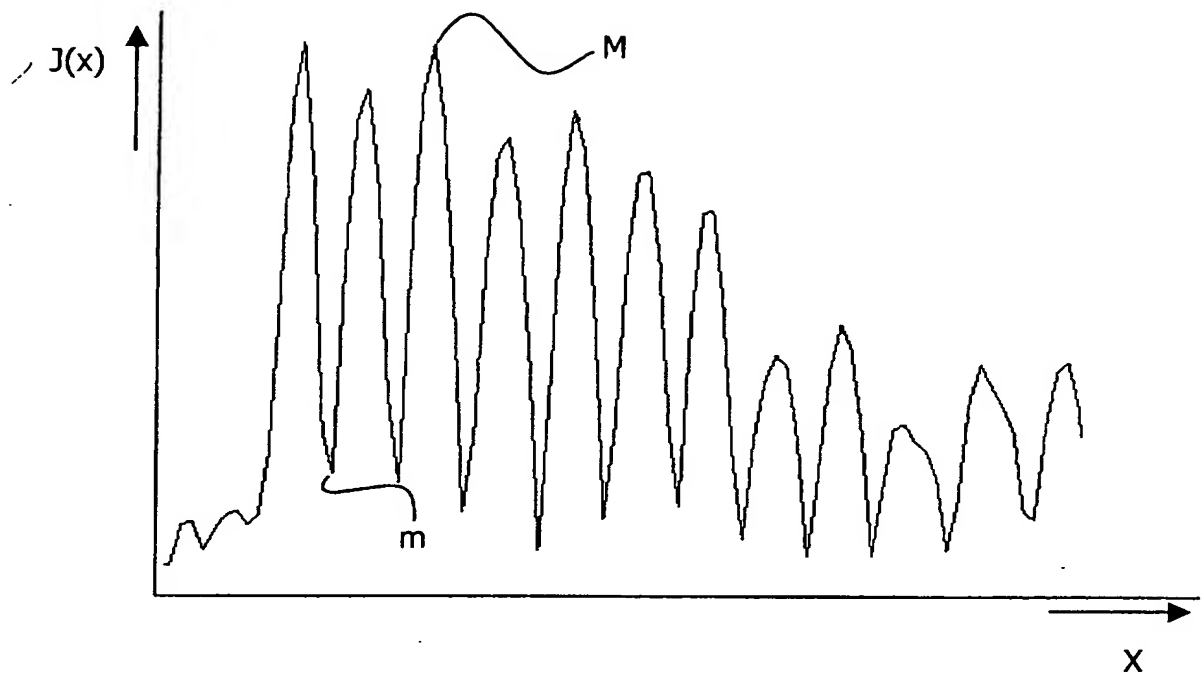


FIG. 2

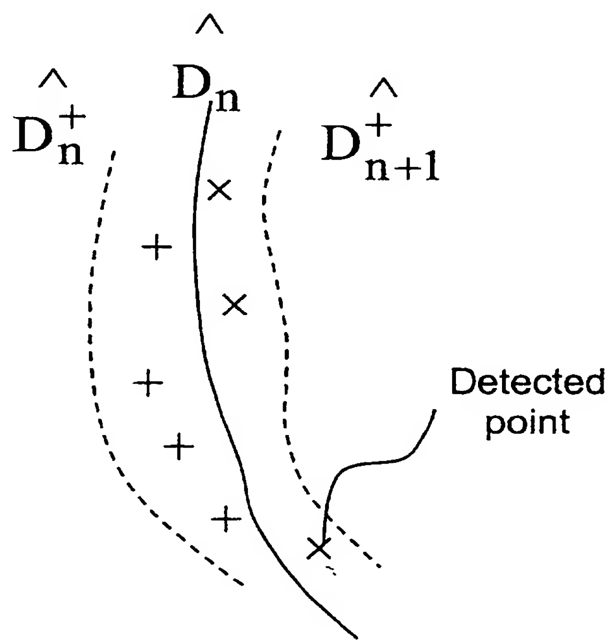


FIG.3

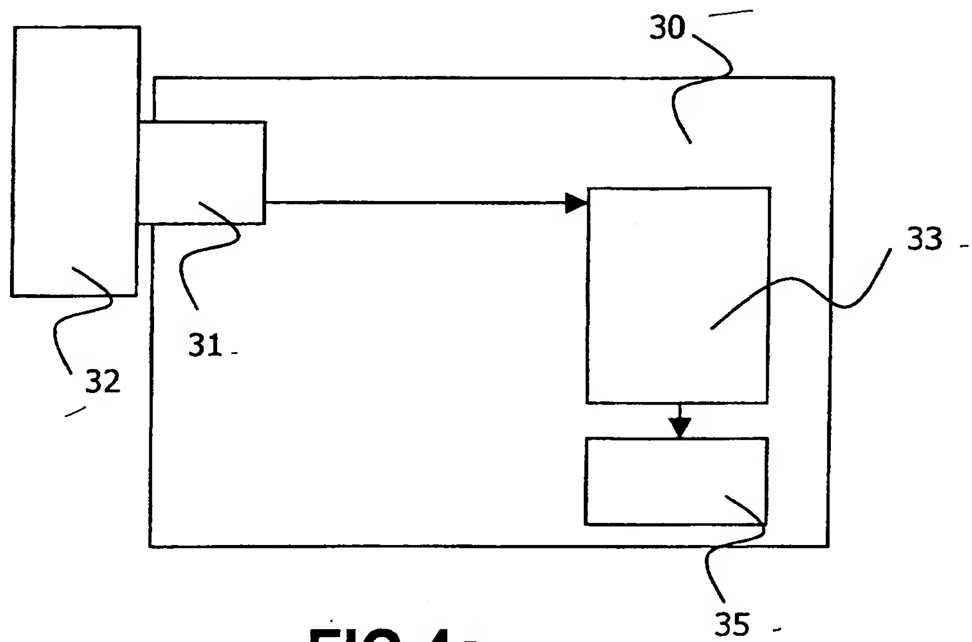


FIG.4a

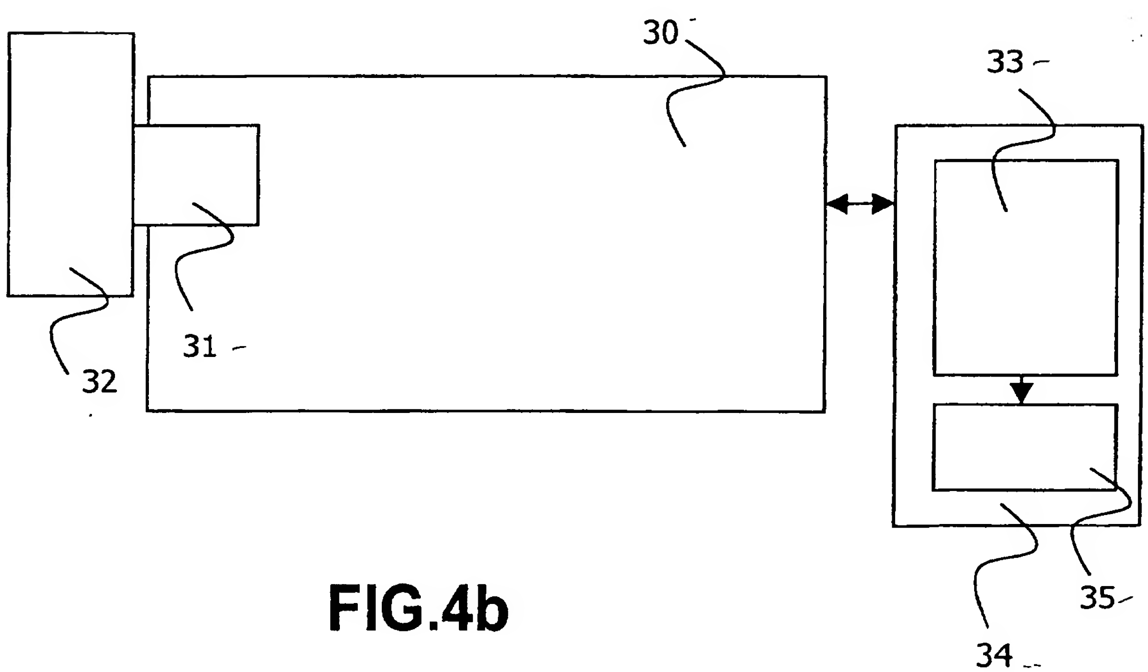


FIG.4b